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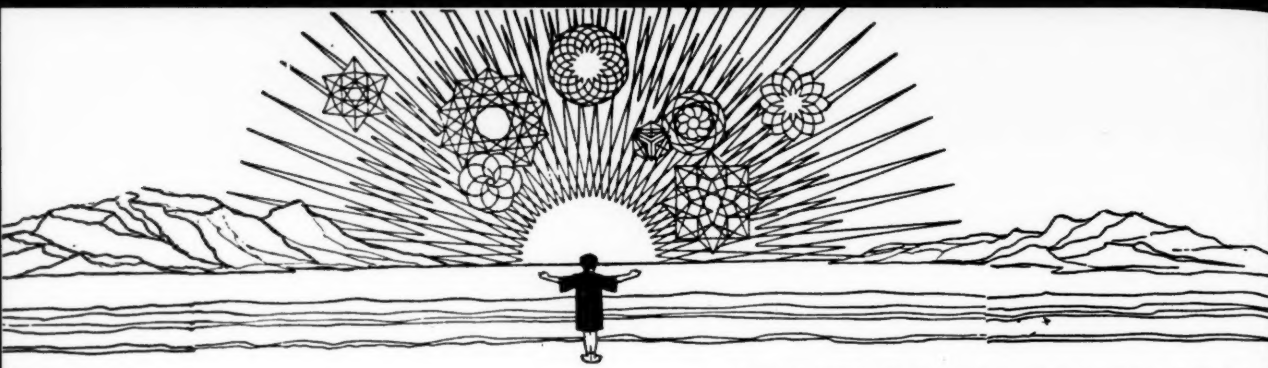



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**A cooperative journal to promote the free association of those working toward the integration of all knowledge through the study of the whole of things, Nature, Man, and Society, assuming the universe to be one, dependable, intelligible, harmonious.**

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# INTEGRAL ORDER IN NATURE

Donald Hatch Andrews

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## The Rational Fabric of Music, of Crystals, and of Atomic Structure

THERE is good reason to believe that Pythagoras was the first man to discover integral order in nature. He and his followers were certainly aware of the relation between musical harmony and the simpler integral numbers; and in imagination at least, they explored the possibilities of far broader relationships. According to Aristotle they asserted that the elements of numbers were the elements of all things and the entirety of heaven was a harmonic scale. (*Metaph.* A. 986a). Moreover this was not all idle speculation for it did actually lead to an improved understanding of mathematics; and it also resulted in the founding of a religious cult. Such a dual association has hardly been conspicuous in history since that era, however.

It is interesting that throughout the twenty-five centuries since Pythagoras' time, he has been given substantial honor for his discoveries in music and in mathematics separately; but his broader speculations on integral order in nature have been discounted as close to, if indeed not part of, the lunatic fringe of pseudo-philosophy. It is only within the last twenty-five years that our insight into the fundamentals of nature has been sharpened by laboratory experimentation and refined by modern mathematical thought to the point where we can begin to make something like a rational evaluation of Pythagoras' truly remarkable ideas. And in view of this, I believe that it is worthwhile today to try to integrate the related patterns of music, mathematics and atomics into a kind of neo-Pythagorean philosophy which recent developments in the two latter fields are literally forcing upon us.

I admit at the start that objection may be raised to my claim that Pythagoras discovered the significance of integers in *nature*. The ancient musical stringed instrument and the music produced thereon admittedly may not be a proper part of the natural world; and whether in ancient Greece birds sang in octaves, thirds and fourths I do not know. At any rate, without quarreling over the status of music in nature, let us examine briefly the nature of music.

### *Integral Order in Music*

IN Figure A, I have drawn some simple pictures of a string, the kind of thread or gut which produced the notes from the earliest musical stringed instruments. It is stretched tight between two pegs, one at each end. Thus the ends of the string are held fixed and are unable to move while the main body of the string can go up and down (or sidewise) with considerable freedom.

Starting at the top of the picture, the string in A-O is shown at rest, stretched to form a straight line. In A-1 the string is shown as it might appear in flash photographs taken after it has been struck in the middle and set in its simplest form of vibration in which it bows first up (solid line) and then down (dotted line), the middle moving back and forth from one of these extreme positions to the other; as it passes through the mean position between these two the string assumes for an instant the straight line position shown by the dashed line. In this kind of motion (technically a *steady state*) it is vibrating at a *constant* pitch or frequency. For example, if it happens to be a string with the mass factor and tension so that it is tuned to *middle C* it will move down and up making a round trip 256 times each second.

This is all, in one sense, kindergarten physics and one might think that the detailed description of this simple process is wasted effort. Yet the discoveries in atomic physics in the last half century have shown us how imperfectly we understand even today the basic significance of the repetitive integral wave pattern in which time, space and integral order merge into a kind of universal form. So I think that a careful examination of the fundamentals of Pythagoras' string can be rewarding.

First of all we must be aware of the significance of fixing the ends of the string in a rigid position so that they cannot move. This is what the mathema-

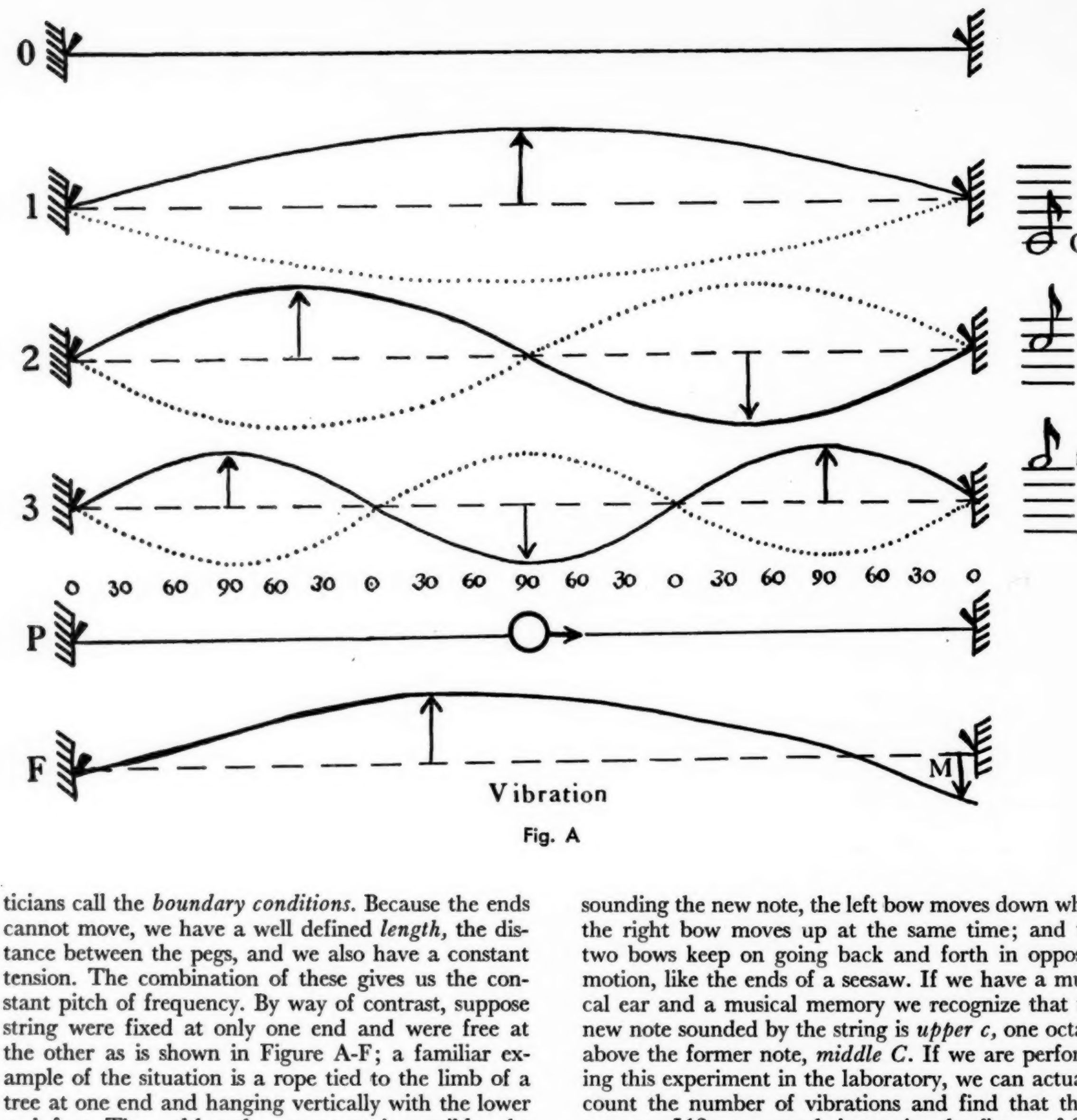


Fig. A

ticians call the *boundary conditions*. Because the ends cannot move, we have a well defined *length*, the distance between the pegs, and we also have a constant tension. The combination of these gives us the constant pitch of frequency. By way of contrast, suppose string were fixed at only one end and were free at the other as is shown in Figure A-F; a familiar example of the situation is a rope tied to the limb of a tree at one end and hanging vertically with the lower end free. Then although movement is possible, the vibration pattern is very complicated and there is nothing like a single note.

Now returning to our string which is pegged at both ends, suppose that we can press down on the middle of the string for a moment and then pluck it at a point one quarter of its original length from one end. In this way (or by more refined methods) it can be set in motion such that a flash photograph will show it in the form which I have drawn in Figure A-2. Now, when the string is at one extreme position as shown in the solid line, there are two bows, one upward and one downward, while the middle point is stationary at the position it had originally before there was any vibration. As the vibration continues, sounding the new note, the left bow moves down while the right bow moves up at the same time; and the two bows keep on going back and forth in opposite motion, like the ends of a seesaw. If we have a musical ear and a musical memory we recognize that the new note sounded by the string is *upper c,* one octave above the former note, *middle C*. If we are performing this experiment in the laboratory, we can actually count the number of vibrations and find that there are now 512 per second, just twice the figure of 256 which we had before. In other words the numbers of vibrations per second in our two experiments are in the ratio of 2:1 while the length of the bows are in the ratio 1:2. This is the relationship pointed out by Pythagoras.

Now let us hold fixed the points one-third of the way from the left end of the original string and one-third of the way from the right end and strike the string in the middle of one of these segments. We now have an even higher note sounding and we recognize that it is *upper g*. If we count the number of vibrations we find that there are 768 per second or exactly three times the number of vibrations which we had in the motion of the string as shown in Figure A-1. If we photograph the string moving in this position

we get a picture looking like the drawing in Figure A-3. There are now three bows, two up and one down if we catch the vibration at the point where the left bow is in the upper position. The ear recognizes this interval of Cg as being something special again, not quite as close a relationship as the octave but still something very different from the relation found when two strings of completely random length ratios are struck at the same time.

We can continue dividing our strings into shorter and shorter segments and get tones which represent ratios such as 1:4, 1:5, 1:6,—a series extending theoretically to 1:infinity. We can also strike strings which have ratios such as 2:3, 3:4 and 4:5. Three strings giving the ratio 3:4:5 would sound the major triad Gce. In the notes produced by these combinations of strings, we have sounds which seem to have more significance to the ear, sounds which can be recognized when repeated, as contrasted with the sounds which come from strings having ratios say, such as 171:232 or 513:605. In other words, the combinations of sounds corresponding to simple integral ratios are more easily remembered; they are more readily identified and seem to have some special significance as contrasted with sounds corresponding to ratios of much larger integers or ratios which might not even have any integral relationship.

It is natural to ask the question now: "Why does the ear recognize these simple integral relationships as contrasted with the more complex relationships?" To get an idea of the reasons behind this, let us imagine that we can photograph the wave in air coming to our ears when the string is vibrating first with the note corresponding to upper c. As shown in Figure B we find that the waves for the upper note are just twice as close together. Now if these two waves can be made to hit the ear at the same time, and we know that they can by striking middle C and upper c on the piano, we then have the peculiar situation where the ear is alternately struck by a single wave crest (c) and then by two crests striking simultaneously (c+C). We might, say, on the odd numbered impact get only the wave crest from upper c striking the ear but on the even numbered impacts get both waves striking the ear. Something must be transmitted to the ear which is received: bang, BANG, bang, BANG, bang, BANG. Somehow or other it is this type of impulse alternating periodically from little to big that gives us the impression of hearing an octave. Certainly one aspect of the recognition of the octave interval is the recognition of this alternating form of impulse.

It is a striking fact that far more people have the ability to distinguish harmonic relations than to distinguish absolute pitch. I think the vast majority of people are like me, who can recognize easily the difference between the Chord Cc and the Chord Cg; but if a single note is struck alone I cannot tell whether it is C or g or any other note. My guess is that less than one in ten thousand people have this latter ability of recognizing absolute pitch. Of course, trained musicians can sense even a small deviation of a note, say middle C, from its exact pitch. On one occasion when the composer Paul Hindemith was coming to visit me, I happened to have a phonograph record of a Beethoven string quartet playing as he arrived. Without stopping for any greeting he dashed through the door, ran into the living room and adjusted the speed control on the record player, exclaiming: "That is an eighth of a tone too low." I doubt whether one person in ten thousand, possibly one person in a million, would have noticed the fact that the record was playing off pitch by this extremely small amount. Yet there are certainly millions of people who would have known instantly if the quartet played two notes in the ratio 1:3 instead of 1:2, granted that they knew that 1:2 was the required harmony at that point.

This fact contains a strong suggestion of the principle that "the whole is more than the sum of the parts." It is certainly true that we perceive relationships far more readily than we perceive a single entity. Thus in integral order, such as we find in harmony, there is something of reality which penetrates our consciousness to its deepest level. And it was the sensing of this principle which, I believe, led the Pythagoreans to the extension of the idea of integral order as a foundation for understanding the whole universe. It is the appearance of integral order in a fundamental role in modern physics and chemistry which will lead us, I believe, to have increased respect for the Pythagoreans.

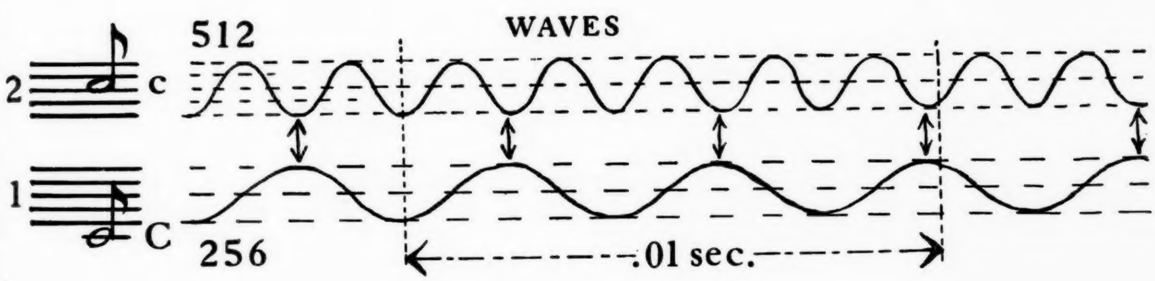


Fig. B

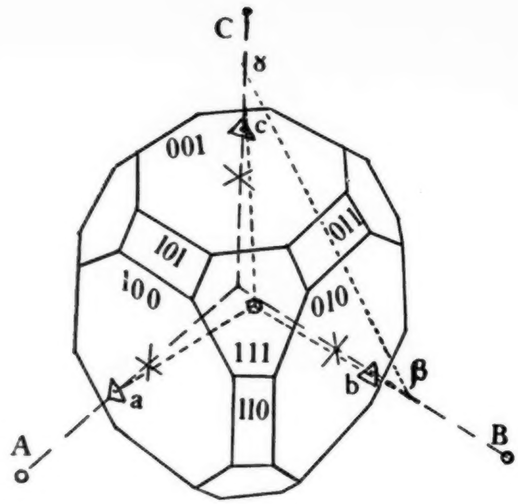


Fig. C Truncated Cube

*Integral Order in Crystals*

IN the development of science in our *Western* civilization, one of the first places where integral order was recognized was in the study of naturally occurring crystals. In the symmetry and regularity of form exhibited by crystal faces scientists early discovered integral relationships. For there was a beauty of design apparent in these crystals which made them a fascinating subject both for admiration and for study. In Figure C I have drawn a typical truncated cube showing three types of crystal faces. In this picture you are looking at the cube with one of its corners pointed toward you, but both the corners and the edges have been shaved off into planes and at an angle. The three original faces of the cube which are visible to you are labeled 100,010,001. Three of the edges have been planed down slightly to produce planes at angles of 45° to the original cube faces; these are labeled 110,101 and 011. Finally the corner pointing toward you has been planed off or truncated to make the plane which is labeled 111.

These numbers represent integral ratios very much like the ratios which we have been using to express musical harmonic relationships. In more complex crystals we might find numbers associated with the faces such as 012, 013, 320, etc., the so-called Millerian indices. They originate in the ratios of the lengths on the crystal axes produced by the intersections of the planes extended from the crystal faces.

For instance, we can set up crystal axes in the form of a coordinate system by selecting a point at the center of this crystal and drawing from it dashed lines which will come out through the center of each of the original cube faces (100,010 and 001), the lines being perpendicular to each of these faces. This gives us the three Cartesian axes at right angles to each other which are frequently labeled A, B and C. We note that each of the original cube faces intersect one and only one axis at points where I have drawn crossed lines like an X. Thus the face at the left (100) intersects the A axis but is parallel to the B and C axes and does not cut them. This is why it has the label or index 100. In selecting the index numbers, the number in the first position always refers to the A axis, the number in the second position to the B axis and the number in the third position to the C axis. Thus in this index the 1 shows that the A axis is intersected at unit distance by the plane of this face, while the two zeros show that the B and C axes are not intersected

In the same way the large face on the right side of the picture (010) intersects the B axis but does not intersect the A or C axis; thus it has the index 010.

Let us now consider the crystal face (011) produced by planing down the right upper edge of the cube. If we draw a line which lies in the center of this plane and extend the line up to $\gamma$ and down to $\beta$, we get intersections with the C and B axis. This 011 face, however, is parallel to the A axis so that if the face were extended sidewise there would never be any intersection with this axis. If we measure the distance from the center of the coordinate system, O, to the two intersections $\beta$ and $\gamma$ we find that these distances or intercepts are the same; that is, they are in the ratio 1:1. We therefore, give this face the index 011. This means that it is parallel to the A axis and intersects the B and the C axes with equal intercepts.

Reasoning in the same way we can draw lines lying in the plane of the face where the corner has been truncated, labeled 111. These lines represent an extension of the plane of this face and we see that it will intersect all three crystal axes; we also see that these intersects are all equal and that their ratios are therefore represented by the triple ratio 1:1:1. This, of course, is the reason for the use of this index, 111.

Many naturally occurring crystals will have faces where the extension of the plane of the face through the crystal axis will give intercepts in the ratio 1:2 and 1:3. Less frequently we will find intercepts corresponding to ratios composed of somewhat larger integers such as 2:3 and 3:4. The striking fact is that all crystals exhibit faces with indexes representable by very small integers. Thus as in music the ear perceived small integral ratios, also crystals so exhibit small integral ratios.

AFTER the discovery of integral order among the intercepts of the various crystal faces, it was natural to ask about the *internal* reasons for this *external* order. Since the crystal is made of atoms, it was believed that there must be an orderly arrangement of these atoms inside the crystal which is reflected in the order of the crystal faces. This speculation was strikingly confirmed by photographs taken with the help of X-rays. Because it has a wave length very much shorter than ordinary light, this X-radiation can penetrate layers of matter which are completely opaque to ordinary light. When there is internal order among

the atoms, the X-rays are refracted or bent from the original path by which they enter the crystal and leave it along lines which make certain special angles with the line of entry. This relationship was worked out by W. L. Bragg and led to conclusive proof of the regular ordering of atoms in crystals.

Suppose we have found a naturally occurring crystal in the form of the truncated cube shown in Figure C. If we study this with X-rays we may find proof that the atoms inside the crystal are arranged in what we might call "cubic order." In other words, if we had X-ray eyes and could look at a portion of this crystal we would see the atoms arranged as they are shown in Figure D. They are packed in orderly rows and columns as contrasted with what we might expect if they were randomly arranged.

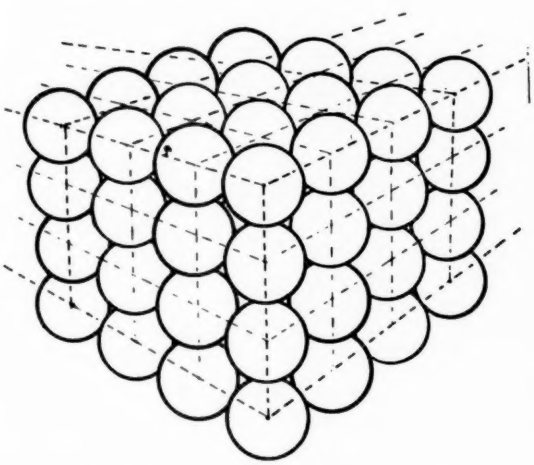

Fig. D Atoms in Cubic Crystal Lattice

**In the above figure the *cubic* structure is indicated by the light dotted lines**

This orderly array of atoms is known as a *lattice*. In a crystal this *lattice* has length, breadth and height, i.e., three dimensions; though the term *lattice* probably suggests to most of us the criss-cross of small boards to make the lattice so popular as decoration in Victorian gardens. These board patterns have only length and height, that is they are *two dimensional lattices,* while the crystal lattice has three dimensions. The term lattice properly applied means a pattern of regular order and refers to the *pattern* rather than the *material* which constitutes the pattern. In other words, it is a term applied to pure form, irrespective of what makes up the form. It is the nature of this form which contains the origin of the integral order in crystals.

Now the reason why a face such as 100 occurs in a crystal is because the plane of this face viewed as a plane cutting across the lattice of atoms will contain atom centers *spaced relatively close together*. This can be illustrated more easily in two dimensions. Suppose, for example, that in imagination we cut off a slice

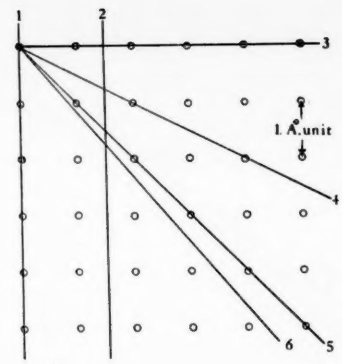


Fig. E Crystal Lattice Cross Section

of our cube from the 100 face,—a slice just one atom thick. This will give us a two-dimensional lattice such as I have drawn in Figure E. A line drawn vertically through a column of atoms such as line 1, is known as a *rational* line. It will continue to pass through atom centers no matter how far it is extended (until it reaches the outside of the crystal). Along this line the atom centers will lie spaced, say, one Ångstrom unit apart.[1]

By contrast line 2 is an irrational line because it does not pass through any atom centers. Line 3 is rational with atom centers also spaced 1 Ångstrom unit apart. Thus Line 1 would lie in the crystal face 100, while Line 3 might lie in the face 001.

Line 4 is also rational, but has the atom centers spaced farther apart, about 2.3 Å units; line 5 is rational and along it the atom centers are spaced about 1.4 Å units apart. Line 5 might lie in a face like 101, making an angle of 45° with the axes. There is no face shown which could contain line 4 which makes an angle of 30° with the horizontal. But if there were such a face it might have the index 012, since it cuts through an atom center on each horizontal row, while moving across *two* columns each time it passes through an atom center.

Line 6, on the other hand, only passes through a single atom center in our picture. If it passed through others when extended,—and it might,—they would be spaced very far apart indeed. It would correspond to a face with an index containing large integers, and the appearance of such a face in a natural crystal is essentially impossible.

We now compare our first two examples of integral order, music and crystals. In music we get integral order because the tone is produced by regular vibration and itself may be said to consist of regular vibration. In other words, there is a regularly repetitive pattern in time; and the simplest relations (harmony) between two of the patterns consist in getting one repeat for one (unison), two repeats for one

[1]One Ångstrom unit (1 Å unit) corresponds to the distance of one one-hundredmillionth of a centimeter.

(the octave Cc), three repeats for one (Cg) and so on.

In the crystal we have a regular repetitive pattern in space and again the relations which occur naturally (the faces) are those which involve getting one repeat for one (011), two repeats for one (line 4, index 012) and so on.

### *Atomic Integral Order*

THIS correlation of space form and musical form actually goes much deeper in nature as shown so strikingly by other discoveries dealing with waves in different forms. One of the best examples is light waves. In the latter part of the Nineteenth Century as the experimental technique for studying light increased in precision, it was found that the colors of light emitted by atoms had certain regular relationships. As Newton had shown, white light passing through a prism was spread out into different colors extending from the red through the orange, yellow, green, blue and violet of the spectrum. Next, laboratory measurements demonstrated that light had a wave-like nature much like the sound waves which we have been illustrating; and because it consisted of regular waves, regular orderly repetition, there was a well-defined wave-length for light of a single pure color or frequency.

In general, white light, such as we get from a very hot object like the sun, spreads out into an even band of color as we see when we pass sunlight through a prism and let it fall on a white surface. On the other hand the spectrum of light from hot atoms of a single variety, say like sodium, can give us sharp lines of color occurring in the spectrum with relatively dark bands in between. Toward the end of the Nineteenth Century the studies of these spectral lines showed that the wave lengths bore integral relationships to each other; and it was largely through the study of these integral relationships that the quantum theory was developed by Planck and by Einstein and applied by Bohr to explain the inner nature of the atom.

First of all, Planck showed that the evidence pointed to the fact that light not only consisted of waves but also had a particle aspect, and Einstein pointed out how Planck's idea explained the way in which light could cause electrons to leave a metal, the photoelectric effect. If light were regarded partly as a stream of particles or *photons* then it appeared that each photon contained an amount of energy (E) simply related to the frequency of the light wave($\nu$). This is the famous Planck relation:

$$E = h\nu$$

This constant $h$ is the Planck constant which has been found subsequently to enter into so many places in nature where integral order occurs.

Just about 25 years after Planck's original proposal, Louis De Broglie showed that it was reasonable to expect that particles of matter would have a wave-aspect just as, inversely, waves of light appeared to have a particle-aspect. De Broglie proposed the complementary equation which showed that the momentum (P) of a particle of matter was related to its wave length ($\lambda$) by the simple equation:

$$P = h/\lambda$$

where $h$ is Planck's constant.

Taking one of the simpler cases occurring in the study of atoms we can see how closely certain aspects of atomic order resemble integral order in music and in crystals. We suppose a single gaseous atom to be confined inside a gas-tight tube which is made of a piece of pipe closed with perfectly flat ends. Next, we imagine that the atom is moving along a straight line at right angles to these ends. Ideally, under these conditions the atom will shuttle back and forth from one end to the other like a ferry boat, bouncing off each end as it hits and reversing its direction of motion. Now it is obvious that in this type of motion we have something which is simply and ideally repetitive and it is not surprising for this reason that we should expect to find integral order. Thus, according to De Broglie's theory, there will be associated with the atom a wave of the same shape that we found in the case of the vibrating string. The wave-length will be related to the momentum of the atom by the simple equation above. Since the wave-length, $\lambda$ must bear an integral relation to the length of the pipe, i.e., since there must be an integral number of bows in the pipe, therefore the equation shows us that the momentum of the particle will be integral multiples of that momentum present when there is just one bow in the wave, as pictured in Figure A-1. The motion with the minimum momentum will have that value which corresponds to a wave-length such that there is one bow of the wave stretching from the left side to the right side of the pipe, exactly the shape shown in Figure A-1. Just as in the case of the musical string where we find that the ends of the string must be fixed and incapable of movement if we are to have the simple natural series of vibrations, here we conclude that this mysterious wave associated with the motion of the atom has its ends fixed at the points where the atom collides with the ends of the pipe. I have illustrated this again in Figure A where the line labeled P shows the path of the atom in going back and forth between the two ends of the pipe which are located here directly below the pegs of the string shown in Figures A-1, A-2 and A-3. Thus the figures which I have drawn for the vibration of the string will now be absolutely identical with the wave pattern which we associate with the vibration of the atom going back and forth between the two ends of the pipe. We will find that the wave length will be such that we can have present one bow as shown in Figure A-1, two bows as shown in Figure A-2, three bows as shown in Figure A-3, etc. with a corresponding set of frequencies in A-2 being exactly twice that in A-1 and the frequency in A-3 being three times that in A-1. If we could "listen" to the waves associated with three times, four times and five times respectively

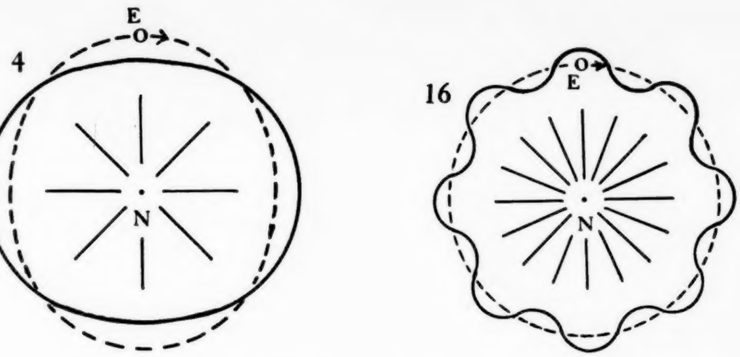


Fig. F Electron Waves in Atoms

the fundamental shown in A-1 we would certainly "hear" the three atoms "singing" the chord corresponding to the major triad.

I am sure that this last statement will be challenged by a great many theoretical physicists and I am not sure that my liberal use of quotation marks is a sufficient defense. There have been many intense arguments about the reality of these waves. Certainly our primary reason for speaking of the waves here in the case of the atom lies in mathematical relations which have been uncovered in such unlikely places as the measurements of thermodynamic properties of gases such as the heat capacity and entropy. There is a long chain of logic stretching from the experimental measurement to the mathematical wave. No one has ever seen or heard such a wave. The frequency usually is many octaves too high for the human ear to hear and the essential nature of the wave is far different from the sound wave which the ear naturally perceives. In fact the mathematics indicate that these waves have an *imaginary* component involving the mathematical *imaginary* quality, the square root of minus one.

My own feeling is that the label "imaginary" which mathematics has attached to these quantities has led to a subconscious feeling on the part of many scientists that the waves themselves must be imaginary. When one begins to discuss the nature of the existence of such quantities one gets into one of the most obscure regions of the current philosophy of science. I cannot take the time at this point to go into the semantics and the philosophy of this question. I do want to stress the fact, however, that we have a close analogy here between the fundamental form which appears mathematically in connection with atoms and the fundamental form which we literally hear and see in the vibrating string. The integral order in each is identical; and I believe personally that the former has as much claim to the term *reality* as the latter. (See Appendix.)

The De Broglie wave becomes a little more complicated when we consider the behavior of a particle *inside* an atom. For example, the hydrogen atom consists of a nucleus at center with a positive electrical charge and an electron with negative charge which circulates around it, like a planet around the sun. Suppose that we have a circular orbit; then we believe that in certain respects the wave will also be circular in form. In other words, the ends are not fixed as in the case of the vibrating string, in fact, we have no *ends* since the wave is circular; so our boundary condition is the *continuity* of the wave around the circle. In the case of the straight string (or the wave for the particle in the tube) we had to have an *integral* number of "bows" between the ends because the ends were fixed. In the case of the circular wave we must have an integral number of waves around the circumference of the circle, because where the waves meet there must be no discontinuity.

I have tried to convey a rough idea of this situation in Figure F. Two atoms are drawn. The nucleus of the atom is shown at the center, marked N, and the electron is shown moving around in a circular path, marked E. Waves associated with this path are drawn in. The orbit of the electron without waves is shown as a dashed line and the waves are shown as a solid line. In the figure at the right there are eight wave crests and in the figure at the left there are only two wavecrests, at the left and at the right. Actually the situation is far more complex than I have shown it. These waves cannot be properly represented in a plane drawing on a sheet of paper or even in three dimensions, because they have in part the so-called imaginary dimensions, but they are frequently represented as I have drawn them just to give some idea of the nature of the wave. The important point is that only those waves are permitted where a single bow of the wave will have for its length an integral fraction of the circumference. This corresponds precisely to the condition for the musical string where the length of the bow must be an integral fraction of the length of the string. Thus in the figure at the right we have sixteen bows, eight going out from the circumference and eight going in. Here the length of each bow is exactly 1/16 of the length of the circum-

ference of the orbit of the electron. In the figure to the left the length of each bow is 1/4 of the length of the circumference since there are four bows.

We may summarize the logic of this situation as follows:

The electron, the fundamental negatively charged particle, has, in the steady state, a wave associated with it which is a wave of constant frequency and therefore of a definite constant wave length. Since each bow has the same length, we have a repetitive integral pattern as we proceed along the line which the wave follows. Because this is an integral repetitive wave pattern we have therefore in a given situation only certain definite waves permitted. These correspond precisely to the waves which have for the length of the bow an integral fraction of the orbit, in the same way that the waves permitted on the musical string have for the bow an integral fraction for the length of the string.

One of the major *differences*, however, between integral order in the string and in the atom lies in the possibilities for complexity. In the case of the simple ideal string we think of only one independent parameter or variable quantity which can take on integral values. This may be selected as the number of bows present in the pattern of vibration. On the other hand, even in the case of a simple atom like hydrogen with only one electron, there are several independent variables, each of which can take integral numbers for its values. This naturally results in a more complex pattern of waves. We have elliptical orbits and orbits with precessional motion like a gyroscope. In fact, a closer analogy to the atom would be a vibrating drumhead or vibrating rubber ball where we get a two or three dimensional pattern of vibration with two or three independent variables.

Now, normally in music we do not consider situations like these in studying harmonic relations; but from a more general point of view, the more complex integral relationships of this kind have just as much right to be regarded as harmony, as the relationships found in true musical chords. Thus there exists in atoms a kind of *hyperharmony*, a fabric of integral relationships which is in many ways much like a real musical symphony since it possesses both dynamic content and integral order.

If we now regard a macroscopic collection of atoms such as a crystal or a biological cell, we find an almost unbelievable complexity of relationships. Yet there is good reason to believe that these relationships are still patterns of integral order. The basic pattern stemming from the two fundamental relationships of Planck and of De Broglie has been found so widely and in so many different forms in nature that I believe we can conclude that it is truly universal. Granted that the integers, involved in many even relatively simple cases like a gram of gaseous atoms in a box of cubic-foot volume, would run into values of tens or hundreds of digits even in a single number, still I think it is reasonable to conclude that even there we are dealing with integral order. In fact, even in the multi-celled collection of atoms such as the human body, it looks as if we still must find the *raison d'etre* in integral order.

Now I admit that here is a speculation jumping from a small base to a large conclusion, with a ratio of fancy to fact almost as large as found in Pythagoras' original hypotheses. But I believe that it is a good speculation to keep in mind as we advance into the atomic age.

Sooner or later we all ask the question: "What is the fundamental nature of the Universe?" A hundred years ago science pointed toward a mechanistic answer. Many scientists concluded that the Universe was just a big machine operating under the laws of mechanics, caught in an inexorable fabric of cause and effect. There was little inspiration in this picture, little of meaningful destiny. If, on the other hand, science points toward a universe of integral-order, of hyper-harmony, of a beauty that unfolds in an effectively infinite vista, I think we begin to see the return of meaning to life. It is too early yet to appraise precisely the content of spiritual freedom in this new pattern; but here is something clearly of a different character from the classical deterministic pattern, and we may hope that it will have a hopeful difference. This is why I believe with the utmost conviction that we must strive for this new integrated understanding.

## *Appendix*

For both the red string and for the atom in the pipe, the differential equation expressing the fundamental relations is in the form

$$\frac{d^2 \psi}{d x^2} + \frac{4 \pi^2}{\lambda^2} \psi = 0$$

x is distance along the principal axis, the length of the string of the pipe; $\psi$ displacement of the line of the wave perpendicular to the principal axis; and $\lambda$ is the wave length of the real wave in the case of the string and of the De Broglie wave in the case of the atom.

For the atom, since $\lambda = h/p$ where p is momentum, the differential equation can be written

$$\frac{d^2 \psi}{d x^2} + \frac{8 \pi^2 m}{h^2} E \psi = 0$$

which is Schroedinger's famous equation. This results from the relation: $2mE = p^2$
where m is mass and E is energy.

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# MIND AS THE BASIC POTENTIAL


Alfred Taylor

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## A Biochemist's View that Rationality is Implicit in the Structure of Nature

SIR Francis Bacon gave to science the streamlining which has enabled it to attain such spectacular effects in this modern age. Before this Baconian impetus, science was still in the erratic, uncertain state which had been induced by the long period of church domination. It was Bacon who cleared the atmosphere by a set of principles which radically changed the prevailing Aristotelian tradition. He realized that science must be firmly based on laboratory experimentation and he foresaw that there would be applications to the practical affairs of man all the way from industry to the kitchen.

In the days which have elapsed since the time of Bacon, science has become a sharp-edged tool well adapted for cutting ever more deeply into the unknown of nature, and mankind has become very much impressed by its success. The leaders of other approaches to truth, such as those in philosophy and religion, are often blinded and confused by the brilliance of its technological effects. And even more than the leaders, ordinary men and women have felt the impact of science. Mankind is naturally attracted by success. Life is so filled with disharmonies and stresses of all kinds that we are constantly seeking an avenue of escape. Here is this new star, more brilliant in terms of practical applications than any of the old remedies which have served through the centuries. There is the urge to defy it and the attempt to apply it to the major issues of life and death.

Of course, there is no doubt about the success of science in its own field, and, if the world retains a moderate degree of stability for a few centuries hence, its progress will transcend our most optimistic expectations. But in the main, science is a methodology and must by its very nature be restricted to a particular aspect of the universe.

As a matter of fact, scientists know far less than their accomplishments seem to indicate. By concentrating on limited aspects of the phenomenal world, and by disregarding that which is incompatible with their methods of investigation, it has been possible to build up concepts which are logically consistent and satisfying but which have only a shadowy relation to the total situation. Scientists have tended to do this in order to sharpen the focus of their attack and it is certainly justifiable provided we do not mistake the shadow for the substance.

The research worker concentrates on the tiny aspect of nature which engages his attention. All of us have the tendency to see in the world about us only that which we are looking for and to ignore the rest. From such preoccupation with a few items out of the vast assemblage around us we can come to erroneous conclusions about the big problems which confront us. But this narrowing of attention makes it possible to simplify the world we live in and seemingly to understand it better. It flatters our natural egotism to find that we can answer so many of the questions that arise by this process of oversimplification.

Science has been especially guilty in this regard, partly because of the very nature of its methods of procedure, but perhaps also as a result of its long domination by church and authoritarianism. For a period of many centuries, scientific investigation was obliged to confirm that which was already accepted. A set of beliefs impinging upon the domain of science was maintained by the dogmatic statements of those in power. The atmosphere was rank with superstitions and primitive beliefs which were above question or investigation. When science became free from these stifling restrictions it retained a deep-seated suspicion of any idea or concept which bore the flavor of its days of stagnation, and this attitude remains a decidedly dominant note among scientists today. The result has been the adoption of concepts as far removed as possible from anything with mystical or uninvestigable implications.

With such a background and in view of the nature of the scientific approach, it is understandable that

there would be an effort to explain all data on the basis of chemical and physical principles. The material aspect of the universe appeared to possess a satisfying order of stability. Above all, matter could be investigated and it simplified the theoretical side of research to reduce everything to material phenomena.

The mateiialistic hypothesis has served very well as a guide in the investigation of inorganic materials, but has never really fitted the requirements of the biological sciences. It postulates that during long periods of time the principle of randomization plus the laws of chemistry and physics are sufficient to account for all the varied flora and fauna of the past and present. The assumption has no real support from laboratory data. It is derived as a possibility by leaving out certain key elements in assessing living materials.

For example, those who have studied organic chemistry will recall that one of the great landmarks in that science was the synthesis of urea by the German chemist, Wohler, in 1828. This was hailed as the final substantiation of the materialistic theory since at last we were able to produce a compound in the laboratory which hitherto had been formed only by living cells. Since then, of coure, numerous organic compounds have been synthesized, still further apparently strengthening the validity of the materialism concept. If, however, we consider the total situation, it becomes immediately obvious that the laboratory production of these compounds had no such implications. What difference does it make whether urea is compounded in the laboratory by the conscious intelligence of a living chemist or is made in that chemist's interior by the unconscious wisdom of the body? In both instances it has been accomplished in association with a living organism. In order to make that particular datum fit the requirements of materialism, the mind of the investigator must be ignored. For, if it requires intelligent manipulation to synthesize an organic compound in the laboratory, then it inevitably follows that there must be an equivalent capacity in the tissues of our bodies. In other words, we must recognize that when the tissues of the body produce a particular organic compound, it must be done by a series of steps, which in the laboratory, require intelligent and purposeful direction, qualities which have no place in the materialistic concept.

As stated earlier, scientists really know less than their achievements indicate. Actually our knowledge represents merely a few steps into the domain of the phenomenal world. Anyone who has spent some years in a research laboratory has no illusions in this respect. We know a few things and these have led to a few principles. The practical applications of these have been spectacular. A little knowledge of nature brings power but not necessarily understanding. A man can mount an elephant and make it do useful work but he may have no more than ghost knowledge of that which he controls.

EVERY part and aspect of nature is filled with intriguing unknowns, and living organisms especially remind the scientist of how much he has yet to learn. Those who have spent a lifetime in studying the structures and activities of the human body, for example, are the first to confess that we have only a slight understanding of how it develops and functions. The human body begins as a single cell about 1/125 of an inch in diameter. In this less than a pinpoint of protoplasm is contained not only the design of the inconceivably complex human organism, but also the wisdom necessary to put the plan into operation. Needless to say, scientists have only faint ideas about how all this can be explained.

Further, there is the completed physical man or woman consisting of trillions of cells grouped together in tissues, organs and systems. At every moment, all over the body, there are coordinated movements, formations and transformations which are vital to our continuance. In the human brain alone, there are about 12 billion cells, every one of which is vibrant with life and activity. Each of these cells must be maintained by processes which are most perfectly and delicately balanced to the needs of their living. A harmony and synchronization of functions must exist among these billions of lives as they combine together to form the master organ of the body, the brain.

If we penetrate deeper we encounter strange happenings at the biophysical and biochemical levels of living bodies. It is now known (although its theoretical implications are mainly ignored), that there is a constant turnover in the material constitution of the compounds which make up the body. Matter flows endlessly through the cells and tissues, not for replacement of worn-out substance, but as a natural concomitant of being alive.

Imagine your car being so planned and fabricated that while maintaining its design and effectiveness there was a continuous renewal of every item in every part—the steel, the rubber, the glass, etc., always changing, but without disturbing the efficiency of the whole. Think how impossible it would be for the brain power of all scientists, past or present, even to plan such a mechanism. The living body is inconceivably more complicated than any man-made machine, and the wisdom necessary to develop, maintain, and keep it functioning is, in relation to our understanding, incalculable.

Our profound ignorance of how the adult organism is organized and developed from that tiny point of protoplasm, the ovum, is matched by our meager knowledge of the evolutionary process. Research data indicate that when the ovum begins to grow into a new individual, the germ cells which will form the next generation are set side early in the course of development and are already beyond somatic influence before the organism, in the process of becoming, can have anything more than a hint of its capacity

and experience. A few scientists still maintain that it is possible for the sex cells to be influenced by their somatic matrix, but most workers agree that the data validates Weissmann's theory of the immortality of the germ plasm which was put forth nearly a century ago.

On the basis of this concept, the germ cells form an unbroken line through the various stages of evolution to the present. Hence, the germ cells of our primitive animal progenitors carried the potentiality for a human being, and this potentiality could have been actualized by Darwin's principle of natural selection. This brings the phylogeny and ontogeny of man, as an example, into harmony. During embryonic development, we pass, in a general way, through a recapitulation of ancestral stages of evolution (the Biogenetic Law). Therefore the germ cell contains not only the information necessary for expansion into a completed body, but also something of the record of designs used in past ages for the formation of the ancestral forms.

It was Darwin's theory of evolution, and especially the concept of natural selection, which favored the growth of the materialistic viewpoint which has enveloped science for the past century. It is obvious from our previous discussion that this could only have arisen by removing the latent wisdom of nature from all consideration. It is interesting to speculate in the light of the new data on the continuous flow of matter through living organisms, how we can ascribe the events of living beings to the matter which is only transitorily present in the organism. A consideration of the problem reveals that the design of a living body is all that continues.

It is a truism that we are egocentric by nature and are only following deep-seated impulses when we glorify our ideas and our accomplishments as much as possible. Success in the field of science has given man a basis for a little chest thumping. After millenia of being pushed around by elements of his environment, such as weather, earthquake, disease, etc., he is at last able to demonstrate that he has some capacity to control things himself. He receives special satisfaction from now having the power to do that which, in the days of his enslavement to superstition, was considered to be in the province of invisible and unknowable forces. He now has a basis for believing that as long as a thing is investigable he will sooner or later understand how to control it. Hence, the great reluctance on the part of so many scientists to give up the materialistic hypothesis, even when the data in his possession have made it untenable.

It is quite obvious that scientists, even though their understanding represents merely the first tip-toe into the knowledge of nature, have nevertheless acquired the power to know and to do in many directions. But that same penetration which has given them this power is progressively revealing how vast is the unknown in relation to the known. This is exemplified by the vivid contrast between our knowledge of the human body and the wisdom necessary to develop and maintain its incredible complexity. To assume that this inconceivable wisdom is merely the result of the blind interplay of matter and energy in space is recklessly to ignore the recognized data of science. The materialistic hypothesis assigns to matter properties it has never been shown to possess. Therefore, to apply this concept to the evolution, development and growth of living beings is to fall into a pit of superstition on a level with that from which science emancipated itself in medieval times.

The progress of science is tending towards the unification of the various aspects of the phenomenal world. The concept of evolution which, in modern times, was first successfully applied to living organisms, must now be extended to include the chemical elements of inorganic materials. The next step, the linking of the living and the non-living into an integrated whole on the assumption that they are expressions of a common basic potential, is inevitable. This potential, for lack of a better designation, can be called the wisdom of nature. We shall mean no more by this phrase than that the more we know of the processes of nature, the more they turn out to be rational, in the strict meaning of that word.

What is the knowledge towards which scientists are striving? Is it not that which is already both immanent and active in the world around us? For example, in every living organism, there is a performance in chemistry which makes our knowledge in that field, by comparison, microscopic. The biochemist by his researches attains to a little understanding of the vast knowledge which is inherent in every one of the trillions of cells of his own body. He succeeds, as his work progresses, in tapping, in some measure, this hidden chemical wisdom. It then becomes possible for him to apply his knowledge to the problems of health and disease.

To recognize the wisdom in nature does not in any way circumscribe the capacity of science to investigate any or all phenomena. Chemistry is based on an inferred structure of matter. The chemist deals with entirely hypothetical units of material substance, but the progress of his science has not been handicapped because of its dependence on something hidden from sensory contact. His observations and experiments are confined to gross matter and from the data so obtained he deduces the underlying structure. Any force or characteristic which manifests itself in terms of sensory data is open to laboratory investigation.

Research data indicate that there is a varied expression of the wisdom of nature in the material world and that particular designs and patterns are united to produce a crystal, a plant or an animal. Each higher expression contains as much of the lower as can be used.

The living organism utilizes the principle of chemistry, for example, in an ever increasing order of complexity from the relatively simple inorganic up through organic and biochemical manipulations. The same is true for the structural design of plants and animals. A human body is composed of a hierarchy of anatomical units. There are certain relatively free-living leucocytes, or white cells, in the blood stream which are able by means of ameboid movement to pass through the walls of capillaries into adjacent tissues for the purposes of clearing up invading bacteria or other foreign substances. At the other extreme there are nerve cells in the human brain which attain to a high degree of specialization. The basis of growth is cell division and the details of how it occurs in human tissues is essentially the same as it is in the cells of a plant or a fly. Other instances could be cited which demonstrate the coordinated expression of a silent wisdom throughout the world of the living.

There is also the wisdom that is demonstrated at a still higher level when the animal, as an independent unit, displays intelligence in its relation to other forms and to its environment. One of the most striking examples of this, which has recently been thoroughly established by research, is the ability of the honey bee to communicate to its fellow workers in the hive the direction, distance and quality of a discovered food supply. This is done by a dance, the design of which conveys the information. It is obvious that such a performance necessitates the use of abstract symbolism and the capacity to remember the details of something experienced previously. This is an example of intelligence at the insect level of evolution and it also represents another facet of the same wisdom which guides the inscrutable chemical, physical, structural, and physiological activities of the bee's body.

The human mind is not only quantitatively superior to the animal mind but there is a qualitative difference which leads to self-awareness and conscious thinking. Scientists are able to discover the truth in nature by laboratory investigation and they can do so through mental activity which is independent of the manipulations of materials. Archimedes discovered that $\pi$ can be calculated theoretically without making use of the quantitative data obtained by measurements and the concept so developed applies to the ratio of circumference to diameter of any circle. Many brilliantly successful theories, especially in the field of physics, have originated through purely mental structuring. Einstein's theory of relativity is a good example of this approach to truth. The evidence indicates that, to the degree we can manifest it, there is a potential in human mind which, when formulated, equates to the processes in our bodies and in the matter-energy-space of our universe.

As we examine the material world we find a correlation between capacities and structures. Qualities are revealed in complex chemical compounds such as proteins which are not evident in simpler molecular structures such as table salt. There is an increasing display of new characteristics as we go from the individual living cell to tissues and on up the scale to the whole organism. It is true that the structure and functions observed in the human body are potentially present in the single cell from which it originated, and an oak tree is latent in each of its numerous acorns. But we do not study acorns to learn about oak trees and there is no evidence of the human body and its capacities in the originating germ cell.

The same difficulty is involved when we attempt to find the living in the principles governing matter at the mineral level. Metaphysical teachings of the past have stressed that the universe is mirrored in each atom, just as the oak tree sleeps in the acorn, but the point is that nature, at the mineral stage, is inarticulate about its higher possibilities, Hence, it becomes just as irrational to attempt to reduce the living to the much narrower expression of nature found in the mineral as it would be to try to make the oak tree conform to what we can observe in the acorn.

It seems rather strange that science which, with every advance, reveals more of the mysterious harmony and wisdom of the universe has, at the same time, through philosophical extensions of its knowledge of material structures been a decisive factor in dulling man's appreciation of the order, the beauty, the wonder of his world. Man has through science been emancipated in some degree from the superstitions of medieval times, but the alternative, the so-called realism of the present day, has taken him from the frying pan into the fire.

Perhaps now that the two extremes have been endured, a middle way will emerge. We all agree that science must never compromise its emphasis on the laboratory approach, its insistence that all theoretical formulation must stand or fall on the test of research, and its refusal to bow down to any authority other than the data derived from repeatable observation and experiment. To maintain these objectives, theoretical concepts must be lightly held and easily cast aside as increasing scientific knowledge makes them untenable.

Dr. Taylor did his undergraduate work at the Universities of California and Oregon, and his graduate training in experimental biology and biochemistry at Oregon State College, where he received his Ph.D. degree. He is at present a research scientist at the Biochemical Institute of the University of Texas.

# SOURCE READINGS: INTEGRATIVE MATERIALS AND METHODS

## Evolution as a Creative Process

"IN 1694, a Dutch microscopist, Hartsoeker, thought that he saw a tiny, but complete, human figure, a homunculus, in the head of a human spermatozoon. We should not reproach him too unkindly for his mistake. His microscope we would doubtless regard as a very poor instrument; even with much better microscopes modern biologists sometimes manage to find what they want to see rather than what is actually there."

The lead article in the Winter (December 1957) issue of *American Scientist* opens with the above words. Theodosius Dobzhansky, the writer of the article, entitles his contribution: "On Methods of Evolutionary Biology and Anthropology," and in the dozen pages devoted to biology he surveys the history as well as the current trends of biological thought, discussing the evolution of certain biological concepts, and tracing the adaptations they have undergone.

Speaking of the "preformationist" viewpoint, he says: "Nowadays nobody believes in homunculi, but the preformist way of thinking is very much alive. It makes some difficult problems appear deceptively simple. The body of adult man is composed of some $10^{13}$ cells, and contains about 7 x $6^{26}$ atoms. Just how do these atoms and cells manage to band together to produce a living, sentient, thinking, and willing person? They have accomplished this feat through a process of evolution, by way of innumerable transformations of something like a simple virus to protozoans, to worms, to fishes, to reptiles, to mammals, to man." In evolutionary thought, preformist ideas usually take the form of theories of orthogenesis. These theories propose that, whatever the emergent (present) form of an organism, this form must have been a "potentiality" in its ancestors. Like all theories of "evolution from below" such a theory simply pushes the causative element back to some primordial form, which contained within itself all forms *as potentials;* and thus also the fully-determined futures of all life on this planet.

The alternative to performation is epigenesis. "The original eighteenth century version of epigenesis," says Dobzhansky, "was a vitalist notion, no less crude than its performist counterpart. The sex cells were regarded as mere drops of liquid, containing nothing whatever akin to the body to come. The body was supposed to arise from this liquid owing to the action of some mysterious vital force."

Both of these approaches are unproductive as working hypotheses. Scientifically more productive hypotheses are those which envisage the evolutionary changes as determined by forces the operations of which can be studied experimentally at our time level. Experimental analysis is aided by examination of the evolutionary record, particularly of its historical aspect. Only thus may man learn to understand evolution.

Under the subtitle "Creative Aspects of Evolution" Dobzhansky has this to say: ". . . the numbers of gene combinations that may arise in sexually reproducing species are so immense that none of them is likely to be recurrent, if identical twins are ignored. An individual of a sexual species is, like a work of art, absolutely unique. He is like a work of art also in another respect, because . . . an important restriction is imposed on gene combinations. The gene combinations which survive are coherent, harmonious, and adapted to eke out an existence in some environments which exist on our planet. A living organism is a masterwork, because it remains alive in environments which are often hostile. To a human observer a living body has, when he comes to know it, esthetic value.

"The freedom of evolution is, accordingly, restricted in one very basic respect. Only what can survive does. Innumerable potentially possible gene combinations that are unfit to survive are either not formed at all or are eliminated. We may, then, agree with adherents of theories of orthogenesis that evolution is guided, and that it 'proceeds according to laws.' But the guidance and the laws are not orthogenesis. Man was not preformed or 'infolded' in the australopithecines or in whatever other ancestors he developed from, not even in the sense in which a flower is preformed in the bud. On the other hand, neither was the appearance of man an accident, in the sense in which a hand of cards is accidental. Man is a product of a long evolutionary history . . . The elementary events of this history are mutations. Mutations are determined by the structure of the gene which mutates, and this structure is in turn determined by the evolutionary history of the gene. The gene, the individual, and the species, are time-binding machines.

"Evolution is a creative process. It is creative by any reasonable definition of creativity. It is unique, unprecedented, unrepeatable, and irreversible. It leads to emergence of beautifully contrived mechanisms of living bodies. And it constantly runs the risk of ending in a failure which is extinction. The evolution of man or of any other species has not been predetermined. Man was not preformed in his remote ancestors. No intelligence but a divine one could have foreseen the emergence of man before he actually appeared, just as no human intelligence can yet be certain whither he is going and what is his ultimate destination."

—*Alan Mannion.*

## The Implications of Atomic Power

THE Twelfth American Assembly met on the campus of Columbia University in October 1957 for a three-day discussion of national and international policies and programs in atomic power. (The American Assembly is a program of conferences which bring together business, labor, farm groups, the professions, political parties, government and the academic community, to develop recommendations on national issues.) The Final Report, together with a number of background papers, has been published as *Atoms for Power*. The contents include an introduction by Philip C. Jessup, and papers by Robert Oppenheimer, Oliver Townsend, Walter H. Zinn, Klaus Knorr, Sir John Cockcroft and Max Kohnstamm.

Dr. Oppenheimer defines the purpose of his paper, "The environs of atomic power," to be a description of "some of the territories surrounding atomic power, some of the issues and problems, some of the places where atomic power intersects other enterprises and other fields of policy or dispute." The first part of the article reviews the historical background and discusses earlier views of the relationship of weapons to power and the tools of science.

Atomic energy has come to be a symbol of something that is real; the important, hopeful, new, and complex role that science and technology play in today's world. Not only in the United States but in many parts of the world an interest in atomic power has been the taking-off place for a new attitude toward the cultivation of science and the training of scientists. In this country, for some years, the Atomic Energy Commission was the largest patron of basic research in the physical sciences. This represents something far more general and potentially significant than an attempt at the economical and practical production of atomic power. Dr. Oppenheimer believes that we are seeing here a fostering and a recognition of one of the traits of our time.

Other considerations have affected the development of atomic power. Most of the knowledge on which the atomic energy program was based, acquired between 1900 and 1940, although understood only by a few specialists, was open knowledge. During the war, however, all work done was secret. There was undoubtedly wide duplication caused by the secrecy, but the principal effect lay in a kind of thinning and impoverishment of communication. Although secrecy was only one of the blocks to more rapid progress, Dr. Oppenheimer says, "My own view is that complete freedom and openness in publication and communication make for the most rapid progress and for the most well-founded judgment."

The paper reviews the hazards that go with the development of atomic energy, the availability and distribution of raw materials, the development of atomic power abroad, and the American monopoly, which the McMahon Act sought to preserve. Of particular importance was the Acheson-Lilienthal Report, which took cognizance of the considerations set forth in the McMahon Act, but gave indication of the conditions under which the United States could assist in liquidating its monopoly and participate in international cooperative development of the peaceful aspects of atomic energy. The McMahon Act became law, while the Acheson-Lilienthal Report remained a paper. Had it not, Dr. Oppenheimer writes, "We should have had both a sign and a portent for a radically different Communist policy, a radically different Communism and, in general, a moderation of all extremes of nationalism. We should have had a beginning of that *open* world of which Bohr then and often later was to speak; there would be neither atomic bombs nor atomic secrets."

Four years ago, President Eisenhower proposed the program of *Atoms for Peace*, from which has grown the International Atomic Energy Agency. But, Dr. Oppenheimer says, "Whereas in the Acheson-Lilienthal proposal the international cooperative development of the peaceful uses of the atom had had a substantive, functional and firm connection with atomic disarmament, the *Atoms for Peace* leaves this question not directly touched; its bearing on the prospects of nuclear war is at most allusive and sentimental."

Today it is sometimes thought that our policies with regard to atomic power and our willingness to assist abroad in its development may be a deterrent on other countries to acquire atomic armament. Dr. Oppenheimer has his doubts about this, and feels that if we wish to limit the countries making atomic weapons, the best way would be to share our responsibility for their use with our allies abroad. He concludes:

"In 1947 Mr. Stimson wrote, 'The riven atom, uncontrolled, can only be a growing menace to us all.' And then he went to to say, 'Lasting peace and freedom can not be achieved until the world finds a way toward the necessary government of the whole.' We think, of course, of a government having some analogy to our own experience. . . . I do not suppose the world has ever looked less hopeful for such an undertaking; and even if it were not for the Communists, it would not look very hopeful.

"Nevertheless, in our world, the nature of our defense problems pulls us together; the nature of our economic development pulls us together; the nature of the communications provided by technology pulls us together. Before one can have any hope of even limited federation on a larger scale, there has to be a common human community. This can not be global. . . . [But] the whole nature of our world is such that we are bound together in a transnational way, technically, economically, scientifically, culturally, by communities which are more loosely related to each other

within a country than they are within themselves through the whole accessible world. This is in the nature of knowledge today, in the nature of competence. If the nations provide the warp of our life, these communities provide a kind of woof.

"Atomic power . . . will make possible undertakings that would have been foreclosed without it. In our dealings with other parts of the world, Americans will work with men of many countries; this they do today in countless enterprises for enlarging the understanding, increasng the civility, and deepening the spirit of man. If we see atomic energy as an example . . . it will play its part in creating those communities, those true elements of federation, and that pattern of new order which will some day have to encompass this earth, if we are to live with the great new powers we have acquired."

—*E. B. Sellon*

## The Common Ground of Longing

EVER since Freud took the lid off the unconscious and revealed the more squalid side of human nature, it has been rare to find someone in the clinical setting who believes man is basically loving, that the primary drive is for love and relatedness to others. Dr. Robert Murphy, Jr., psychiatrist of Waverly, Pa., in a meeting on Nov. 22-24 at Pendle Hill, Wallingford, Pa., sponsored by the Society of Friends, presented such a view.

According to him, man's primary drive is toward the experience of love, to escape from loneliness. This is the same thing as a drive to know the meaning of one's existence, which is in relatedness to others. There is no energy so powerful as this basic drive which Dr. Murphy labels as longing.

The other instinctual drives, aggressions, sex, etc., stem from this longing and are secondary drives. The effort to destroy what seems to stand in the way of one's ability to love is basically delusional. Common ground exists among all men and waits to be discovered. The destruction of other men (as the Germans' of the Jews) is a premature discharge, through projection outside of oneself, of anxiety which has become unbearable.

Both the basic drive and the instinctual drives are profoundly unconscious for the most part. We are seldom aware of them and at most only of their surface layers. The longing is conscious in the infant's longing for the mother, in the yearning experienced before sexual union, and in the saints' and mystics' longing for union with God. In these three instances the longing totally consumes the individual, but ordinarily it is not in our awareness.

In health the instincts subserve the basic drive. When the sex drive is serving the longing, there is a mature sexual attachment. When aggressiveness is held to the desire for relatedness, there is a penetrating curiosity about life which seeks bonds below the surface. This is very strong because it is in the service of the basic drive.

Anxiety is produced by any threat to the basic drive. Dr. Murphy believes that the meaning of being human is to have the capacity to relate oneself in constantly expanding circles. There is a constant flow of energy to reach out to the world, to know the meaning of life. When the instincts are not serving this end anxiety results. At the deepest levels of the unconscious, anxiety is fear that one's existence is in danger of becoming meaningless. Anxiety is a signal that the meaning of one's life is being threatened.

When the instincts are not serving the longing, they drain off anxiety. Aggressivity and sex activity reduce anxiety at least temporarily. Our culture devises so many outlets and distractions that we are constantly getting rid of our anxiety. According to Dr. Murphy, this is a loss because anxiety is an opportunity for growth if it is not dissipated.

He describes anxiety as a universal and cosmic experience which we must learn to grasp and not let escape. There is deep value in the emergence to consciousness of unconscious anxiety. If we can just wait or "not do" rather than draining it off, we may learn something new and insightful about ourselves or about the person who evoked the anxiety and thus gain control and mastery. It means totally mustering our alertness to learn the meaning of the experience. Nurturing the anxiety without acting on it or without draining it off can lead to real insight.

Dr. Murphy characterizes the peculiar quality of emergence of insight from the unconscious as like a sunrise. One waits in darkness. Then he thinks the dawn might be coming, when suddenly there comes a point when he knows the sun will burst forth inevitably. Anxiety is the tool for such emergence. It has an unerring accuracy in seeking the unconscious depth at which the insight is to be loosened up.

If we can wait and "not do" we can use anger to increase our own growth rather than cut others down. The fury slowly becomes less chaotic until it resembles a deep ground swell rising from the unconscious. Behind this diffuse anger is the ability for self-forgiveness and tenderness. The emergence of this capacity is a really great step toward growth.

In discussing the place of the will in change, Dr. Murphy admits there is some truth in the view that we can will ourselves to be different. But the will is not to be used as a battering ram. Rather it is a delicate and beautiful instrument, a feeble force which can move a great deal. When it faces the surface layer of the unconsciousness which is naked and uncivilized emotion and rage, it is apt to disrupt the process which leads to insight, to interfere with "not do." But it is

will which controls all the motor outlets and thus will is capable of producing "not do." Will is conscious only and unable to penetrate the unconscious layers. But it can seek anxiety which is at home on all the levels of consciousness. This then can lead one to insight which emerges from the unconscious and reveals the meaning of existence.

—*S. J. Nicholson*

## Fresh Clues to the Mystery of Brain Functions

IN the issue of *Science* for January 10, 1958, H. E. Himwich presented a paper on "Psychopharmacologic Drugs." Not only does this article present considerable original material, but it summarizes the findings of others in several related areas as published in eighty-six other papers which are listed.

Considerable new data on the action of a number of tranquilizers and other psychopharmacologic drugs are furnished. It is of importance that drugs are now available which, when properly used, so reduce the excitement of the mentally disturbed as to bring them tractably within reach of psychotherapeutic contact and communication. It is also of some importance that pharmacologic means are available for reducing the stresses of life transactions for those who, for valid reasons, may be helped temporarily by such means.

The article by Himwick does not discuss the use of tranquilizers as escapes. But it does furnish important material about the functions of the brain which these drugs now make available. A detailed and illustrated discussion of these findings constitutes the major portion of Himwick's paper.

Tranquilizers of various types act by affecting an equilibrium between various hormones (serotonin, acetylcholine) which mediate the transmission of nerve impulses across synapses. Evidence seems to point that psychoses and neuroses are (at least in part) the results of disbalance in the optimal amounts of these hormones.

"[While] . . . the barbiturates . . . act most strongly on the later-developed parts of the brain—the cortex and cerebral hemispheres—[and] . . . depress functions . . . concerned with the analyzing mechanisms of vision, audition, and other perceptive functions . . . as well as thought and memory . . . the tranquilizers also affect functions ascribed to the cerebral cortex, their most potent actions are exerted on the subcortical structures regarded as parts of the anatomic substrate of emotion: the mid-brain, reticular formation, the hypothalamus, and the components of the rhinencephalon."

Because of this, and because these drugs are highly selective as to the anatomic formations in which they replace normal deposits of the natural hormones, the beginnings have been made toward a more complete understanding of the functions of these mysterious mid-brain structures.

Since it is now becoming apparent that mediation by the mid-brain systems of both afferent and efferent stimuli to the cerebral cortex also constitutes mediation of awareness, thought and perception, the possibilities of identifying more extensively the nature of this mediation function are enormous and important. From the numerous findings already reported in this paper, it would seem that, as tranquilizing drugs are further developed, even greater and more detailed knowledge of the functions of the thalamus, the hypothalamus, and other structures of the "old" brain will be more clearly revealed.

Evidence points to the fact that psychopharmacologic drugs are not mere tranquilizers in that they tend to reduce "the quantity or intensity of emotional impact on the cortex." Himwich implies that there exists a whole area for exploration of the relation of the mid-brain areas to thought and the so-called higher functions. This implication is contained, for instance, in his statement:

"But it is difficult to see how such an amelioration can change the quality of thought so that the dissociated 'word salad' of the hebephrenic patient can become less incoherent, more logical, and more comprehensible. . . . Decreases in emotional intensity might mitigate the violence in the expression of hallucinatory and delusional material, but again it is more difficult to understand how such a mitigation can cause the correction of schizophrenic mentation. For that change, thinking must be altered in quality." And again, "Certain structures, both cortical and subcortical, are more involved than others in emotional life. . . . Some subcortical regions add a crude awareness, but for the discriminative contribution to that complex function, the cortex must be included in a prominent position. The cingulate gyrus, which is a part of the rhinencephelon but also of the cortex, may be the area where the abnormal elements concerned with awareness and thinking enter into conscious activity. It is not said that rhinencephalic structures do not affect emotional reactions, but it is suggested as a working hypothesis that the cessation of rhinencephalic function is a possible factor in the prevention of the morbid thinking of the schizophrenic."

IN a brief paper, "Response of Single Cells in Monkey Lateral Geniculate Nucleus to Monochromatic Light," written for the January 31, 1958 issue of *Science,* DeValois, Smith, Kitai and Karoly report on experiments involving "tapping in on the visual messages as they are transmitted to the cortex."

In research on rhesus monkeys, they inserted microelectrodes in the lateral geniculate nucleus which consists of six layers of cells separated by fiber layers. "Three of these layers receive impulses from one eye,

three from the other. Thus the visual fibers from each eye split three ways in the thalamus."

The authors were "investigating the functional significance of the laminations of the lateral geniculate nucleus, and, in addition, the nature of the responses of color-selective cells at the thalamic level." Earlier experiments had shown "that the patterns of responses from the laminae . . . differed from one another. On-responses were found in the dorsal layers. In the most ventral layers, [they] observed a striking inhibition of spontaneous activity followed by an off-response when the light was turned off. The responses obtained from the two intermediate layers, although more difficult to interpret, appeared to be a combination . . . with on- and off-outbursts." The current research, in which recordings are made from the activities of single cells, supports these earlier findings.

Some cells have been found in the dorsal pair of laminae "which respond to various narrow ranges of wavelengths in different parts of the spectrum. . . . Thus there seems to be a complete color-vision system represented in the two dorsal layers of the lateral geniculate nucleus."

The authors suggest "the intriguing possibility that there may well be a second type of color-vision system represented in [the two middle laminae], one perhaps having to do with such phenomena as after-images and contrast."

—*Harvey W. Culp*

# A Comment–

## Some Considerations Raised by Andrew Cochran's Theory of the Quantum Physical Basis of Life

THE age-old problem of whether life should be viewed under the aspect of monism or dualism has come up in the discussion between Dr. Cochran and Dr. Johnson in the November issue of MAIN CURRENTS. Both argue ably, although admittedly Mr. Cochran's approach, that of quantum physics, is rather novel. He further supports his point of view by quoting Prof. G. Wald: "I think a scientist has no choice but to approach the origin of life through a hypothesis of spontaneous generation." This statement apparently purports to clinch the argument that a degree of consciousness pervades matter and that it is matter that gives birth to life.

Now, the phenomenon of spontaneous generation may be a new discovery as regards life, but in point of fact it has existed from the beginning of time—long ere life appeared on earth. I have recourse to the snow crystal. The snow crystal *pattern* makes its appearance quite spontaneously, however no one will assert that it is water vapor alone that causes it; an external immaterial agent—frigidity—participates in the process. It is only under the effect of frigidity that the pattern can come into being. Here is palpable proof on a cosmic scale of the action of an extraneous immaterial entity on what is definitely physical; namely, water vapor. With this fact in mind, is it not rational to expect a living organism to be the outcome of a similar duality?

To declare that matter is pervaded with a degree of consciousness based on the theory of the wave nature of matter and therefore life is derived from a lower state in an ascending scale until it culminates in man's consciousness, although plausible, is an assumption; whereas the snow crystal gives evidences of an unmistakable dualism—matter and what passes for life and mind are distinct and independent realities.

The phenomenon of the high degree of the wave nature of matter of the four elements: hydrogen, oxygen, nitrogen and carbon which Mr. Cochran stresses to prove his point, simply means that, if these elements did not have this peculiar property, the special type of organism devised for life would not exist, and matter and *life* could not unite. Just as water vapor is prerequisite to frigidity to cause the crystal pattern to emerge and no other element or chemical compound will do as substitute.

Whether the origin of life is to be viewed under the aspect of monism or dualism, and which of these is the true one, is of vital importance to inquiring man. One might say, that on its solution hangs the fate of society.

—*Adam A. Sanders*

# NEWS AND NOTES

THE crisis in our nation's affairs is now so acute that ultimates have suddenly become topical. The realities having come to the surface, is it too much to ask of mass media that these issues be kept before all of us long enough to result in effective action? Scores of persons, agencies and organizations must begin to work in concert if we are to find the solutions.

To show how clear the issue is, let us draw upon James Reston, Washington correspondent of the *New York Times,* in its issue of February 16, 1958, and notice also an editorial in *Life,* of February 2, 1958, both journals of authentic Americanism.

The *Times* piece quotes Lincoln's words spoken at Springfield, Illinois on January 27, 1837: "At what point then is the approach of danger to be expected? I answer, if it ever reach us it must spring up amongst us; it cannot come from abroad. If destruction be our lot we must ourselves be its author and finisher. As a nation of freemen we must live through all time or die by suicide." Mr. Reston goes on, ". . . while missiles, rockets, launching sites and military affairs in general still dominate the headlines and the debates in Congress, the unresolved crisis of our times, underlying all other crises, is not primarily military but ideological, not external but internal, not mechanical but cultural. . . . The country is aware of the military threat: it is taking steps to deal with it. The same cannot be said with equal assurance about our internal defenses in the fields of education, philosophy or diplomacy. . . . The trouble in the land, said Robert Oppenheimer recently in *Foreign Affairs,* is that the American people have no clear image of the good life or the Government's place in it. One wonders. The trouble is that we do have such a clear image of the good and easy life that nobody even debates it. It is based on the assumption that the production and consumption or enjoyment of material things guaranteed by the Government is in itself the good and easy life, and the crisis is that this assumption has failed us."

The editorial in *Life* calls the battling between the sciences and the humanities nonsense: "It presupposes the continued existence of one branch of learning called science and another called humanities in separate, self-sealing compartments. In fact, it is the separateness and exclusiveness of these studies, almost as much as our real physical deficiencies in science teaching and laboratory space, that is the big trouble with U.S. education. If our schools' need for more and better science courses is clear, so is their need for more and better instruction in history, languages and literature. There is no choice to be made between science and the humanities. On the contrary, our problem is to relate them intelligently and intelligibly to each other."

All this is admirable, but hopes fade when we read what we are to *do. Life's* millions of readers are given the impression that the solution is simple: More high school book reports based on popularizations of science to show students that science can also be literature. Such a proposal is ridiculously inadequate. The disease of anti-intellectualism, which deprives young people of *nourishing* substance from science, starts much earlier than high school and is fostered by the popular magazines of wide circulation.

All through the nineteen thirties and forties, magazines reported that the colleges and universities of America were aware of over-specialization, and of the divorcement of science from cultural education. Nearly every higher educational institution in the country made attempts to solve the problem, but the remedies that were tried—general education, great books, and other economy packages and samples of learning—were (and still are) inadequate. Yet not one magazine of wide circulation gave the kind of help necessary—publicity and editorial support—to make a *sustained* cause out of those endeavors. The crisis is now apparent to everyone, and since fear sharpens interest, the magazines take up the issue. But a problem which defeated the schools and colleges is not to be solved offhand by journalists. *Life,* for example, publishes features and articles on science, but the material is all occasional and descriptive, while its general policy continues to turn upon meretricious sensationalism. None of our major national journals furnish *continuing and coordinated* material which might help citizens seek rational answers to the basic questions: Is the universe meaningful? Is the life of the individual worthwhile? If so, on what terms?

Mr. Reston is in a different position. He speaks sharply about the certainty he feels that the top levels of government are not trying to fill the ideological-educational-cultural vacuum. (The adjectives just hyphenated by us are his own.) He rejects the mechanized, televized, automobilious dream, which advertisers have almost convinced the American public constitutes the "good life." Thus he challenges those who confuse Americanism with materialism. But when he demands that school boards do their duty by reforming the system, he does not point out that earnest, patriotic school-board members have no where to *go* for the help they need. Who is to provide the materials the schools must have if science is to be made a cultural experience for young people, if meaning for man is to be sought in the universe? Mr. Reston blames the gov-

ernment, but the duty is no more there than elsewhere. We ask Mr. Reston first to call upon the *Times*—for which he is such a fine reporter—to help the teachers. Those agencies of public opinion which shape the news can speak editorially, day after day, to those who can put appropriate scholars and scientists to work, in a required *new* way.

The crisis turns on a simple proposition: Do we feel deeply enough about the future of our children, our country and Western culture in general to create the kind of educational experience needed to secure that future? We now *know* what must be done in the schools: it remains to implement the knowledge.

The real need of the hour is simple. It is not to be read, however, only in terms of increased salaries and facilities, "hard core" curricula or personality-adjustment courses. In order to relate the educational problem to the whole of life-experience, we need to begin a program of integrative studies, in one central place, that will demonstrate the fundamental connections between the highest aspects of science and our cultural heritage as a whole. After the material which illustrates those connections has begun to be assembled upon the needed methodological basis, and stated for students, its significant implications could be widely communicated to the public through modern educational devices, such as television. Thus school and home can live one life of the mind. What is called for is not a sharing of the materials of special subjects but the display of inter-related principles so far known. Even those parts of science which are mainly comparative and descriptive (as geology has been until very recently) should not be treated as if they would *never* have structural meaning. No purely informative or popularizing program will do for our over-all purposes, however immediately useful. In addition to creating a climate in which the life of the mind is cherished and respected, we must begin to feed the mind with the materials by which life itself gains significance and value.

Thus our objective is to establish methods whereby the mind is led back from empirical and sensory levels in art and science, where experience begins, to the underlying laws and principles which give meaning to experience. Disclosure of the laws which organized knowledge has so far revealed will make concepts like space, time and causality essential for everyone, not mere philosophical abstractions. The young student who begins with a spontaneous experience of art, language, mathematics and natural science will later find himself at a level where music, acoustics, the structure of matter and the forms and processes of living orders are all held in fee by principles. Such a level is so close to what is beautiful, orderly, just, and *ethical,* that the light will break in upon him. Professor Andrews illuminates this superbly in this issue of MAIN CURRENTS.

The materials we speak of will be of a kind that our public school system can properly employ. It need never be forced on teachers; it must not be formulated into some speculative system or other; it is not to be deformed to fit any dogma. Everyone should have free access to it, and every person and group should make what he can and what he pleases of it. This is the modern version of a very old story: We are to know the truth and the truth will make us free. Without the truths of nuclear physics, no bombs or atomic power; without truth at a higher level, no human capacity to prevent bombs from destroying us or to use atomic power for human good.

Lincoln had the right of it, and we are grateful to Mr. Reston for reminding us, and to the New York *Times,* for providing the platform for his remarks. But we think the country is now also entitled to some sustained action. Mr. Arthur Hayes Sulzberger and Mr. Henry Luce are two of the men in a good position to initiate it. If the thesis propounded herein wins general assent, there are scholars and scientists of first rank who can clarify and amplify, who can give authority, and who can devise the practical program for action.

Newspapers, magazines and television networks can and should help create a favorable climate for a general forward move. To do this, they obviously must state the case in their own kind of language. This means initial collaboration on their part with the scientists and scholars who have specialized in the pertinent studies. They have to command a total understanding of the situation, if the good cause is to be kept in the forefront of public attention until it gets the momentum it requires.

The phrase "good cause" is now rare in some circles, and perhaps suspect in that it may suggest an emotionally charged crusade, complete with slogans, scape-goats, and quick panaceas for all national ills. We conclude, therefore, with the most sobering question.

This country has the executive (if not yet the creative) talent, the technical skills, and the physical resources to afford security, leisure and opportunity for every one of its citizens. At present, it cannot operate primarily for these goals, since military ends intervene. Peace will come, however, since war is now wholly impractical. Technical aid abroad and consequent self-development in assisted countries will make them more and more self-sufficient. When this time comes—and it will probably be coincident with the growing into maturity of our present crop of infants—shall we be ready to make a transition to a new order of things based upon an entirely different world situation? This is the sobering question, and no crusade can be its answer.

Emotionalism only clouds the final issue, more dominant today than in Lincoln's time: "man's inhumanity to man." The crisis which he foresaw is sharpened by forces that can no longer be arranged and contrasted geographically. Then it was North

against South. But East against West is not now the ultimate potent fact. Even the addition of a third dimension, upward into space, does not delimit the situation. The crisis reaches into the life of every man, woman and child, for the failure has its roots in the life of the mind. That failure is everywhere apparent, especially in the lag in that creativity which a free people needs above all.

The answer must come from those who have venturesome minds, intellectual courage, firm adherence to humane principles, and the patience for a long haul. But the beginning must be *now,* for delay is dangerous. An educational reformation, even backed with national resources, takes two or three decades for its fruition in a new generation. Do we have that much time? We can only hope that we shall not earlier be compelled to defend our country's domestic freedom, and that a new and wiser generation can complete the internal adjustment forced upon humanity by the technological changes which, in turn, produce a society of unlimited potential abundance.

—*F. L. Kunz*

# REVIEWS

## Science as a Human Enterprise

IN the midst of the clamor for a crash program in American education designed to produce promptly enough scientists and engineers to meet the challenge of Soviet technology symbolized by the sputnicks, it is well to give thought to the role that science plays in modern culture. In the long run, it would be fatal to over-emphasize science as a means of producing space hardware, supersonic airplanes, nuclear-powered submarines, automated factories, and electronic calculating machines. The scientific enterprise is far more than the production of the mechanical devices and gadgets with which it is so commonly associated in the minds of the majority of the inhabitants of the world.

To be sure, a large number of experts in each of the many scientific disciplines is needed in order to use the rich resources of the bountiful earth for human welfare, not to mention the essential role they perform in developing ever more horrendous weapons for human destruction. But it would be folly if the American educational system were so designed and operated that its principal product is a large number of well trained technicians ignorant of the facts of life in this time of crisis in human affairs and unaware of the social, aesthetic and spiritul values that make life worth living. After all, science is a distinctly human enterprise; in a very real sense it should be taught and appraised as one of the humanities. Certainly, it is imperative that science education should be integrated with all other education at every level of academic instruction.

The two books (*Science and the Creative Spirit,* edited by Harcourt Brown, University of Toronto Press, 165 pp., $4.50; and *Science and Human Values,* by J. Bronowski, Julian Messner, Inc., 94 pp., 1958, $3) now in hand are therefore most timely. They should bring a refreshing breeze to mingle with the otherwise arid winds of contemporary debate. Or to change the figure, they may serve as the catalyst to cause healthy precipitation from the clouds that obscure the sky over many an educational institution and legislative hall.

*Science and the Creative Spirit* is the result of the activities of a Committee on the Humanistic Aspects of Science, appointed in 1950 by the American Council of Learned Societies, with Harcourt Brown as its Chairman. The committee consisted of "individuals who are not practising or professional scientists but who have been interesetd in scientific investigation as a human and social phenomenon and who, working from humane studies, are concerned with developing a better understanding of the role and functioning of science in human history." All participated in the preparation of the book, although its four chapters are attributed respectively to each of four authors.

Following a meaty introduction by the editor to explain why the book was written, Karl Deutsch accepts responsibility for an incisive and perceptive essay on scientific and humanistic knowledge in the growth of civilization. His comments on scientific influences in cultural and social conflitcs and decisions are brief but illuminating and his presentation of the problems of growth and progress as involving a joint enterprise of scientists and humanists is especially constructive. His conclusion that "the core and foundation of both scientific and humanistic work" is, or should be "the deep and self-renewing motivation of men and women to compassionate, merciful, and competent action" has unifying implications of far-reaching significance.

The second essay, by F. E. S. Priestley, deals with science and imagination in English literature and cites many examples of the way in which "Those Scattered Rays Convergent" have yielded rich fruit. Continuing this theme, the editor himself contributes a penetrating analysis of the tensions and anxieties that can be de-

tected by a sudy of science and the literary culture of France. The final chapter, by David Hawkins, emphasizes the creativity of science and grapples successfully, although of course not conclusively, with such problems as those posed by "the participant observer" and by the eternal paradox of "law and will."

The aim of *Science and Human Values* is "to show that the parts of civilization make a whole: to display the links which give society its coherence and, more, which give it life." It would appear that Dr. Bronowski is especially concerned with showing what he believes to be "the place of scienc in the canons of conduct which it has still to perfect." He stresses the importance of "imaginative acts of understanding" as the very essence of scientific activity and traces the influence on conduct of the search for empirical truth. Finally, he finds in the conditions for the success of science "the values of man which science would have had to invent afresh if man had not otherwise known them: the values which make up the sense of human dignity."

Perhaps this whole question of the role of science in modern life and therefore in education can best be answered in the light of Dr. Bronowski's final sentence: "The values by which we are to survice are not rules for just and unjust conduct, but are those deeper illuminations in whose light justice and injustice, good and evil, means and ends are seen in fearful sharpness of outline." The scientist, like every other human being, should be conditioned for awareness of such deeper illuminations. Indeed, the knowledge he is acquiring about the nature of the world and of man may be an important part of the conditioning process, if he occasionally looks at the forest rather than at the individual trees.

—*Kirtley F. Mather*

## Contemporary American Philosophy

PATRICK ROMANELL, Professor of Medical Philosophy and Ethics of the University of Texas, has published a splendid volume of essays, *Toward a Critical Naturalism* (N.Y., The Macmillan Co., 1958, 81 pp., ref., index, $2.35), which bears the sub-title "Reflections on Contemporary American Philosophy." The author explains in his preface that the book ". . . is a brief attempt to arrive at the prime requisites and the essential features of a naturalistic philosophy . . . a Critical Naturalism. . . . [critical in] its insistence on 'continuity of analysis' as the proper method to philosophical problems . . ."

In tracing the development of the new naturalism in America, Romanell associates it with "The decline of the classical, mechanical view of nature in contemporary metaphysics [which is] definitely connected with, if not altogether a consequence of, its disrepute in the new physics of relativity and quantum." The new metaphysics is established upon a faith ". . . in the continuity of man and nature." "The incorporation of man into nature, obviously, *naturalizes* man, but it . . . also *humanizes* nature. For nature with men in it is, after all, vastly different from a nature without them. . . . Consequently, men can neither be reduced to the level of atoms as the naive materialist claims nor raised to the level of the gods as that 'extranaturalist' called the idealist proclaims."

In a chapter on "A Naturalistic Defense of Metaphysics," the differences between scientific knowledge and metaphysical knowledge are expertly developed. The author concludes by stating: "No matter how reliable scientific knowledge is, it is no real substitute for wisdom. . . . Wisdom is irreplaceable. Man does not and can not live by science *alone*. We need more science, of course, but to live significantly we need more wisdom as well. Now, so long as wisdom is wider than scientific information, may not the function of the philosopher be different from that of the scientist? Without denying the theoretical motive for metaphysics, paradoxically enough, perhaps the chief reason for defending its cognitive significance is to justify the validity of its ultimate insight that life is wider than all knowledge, scientific and philosophic."

In discussing "The Logic of Critical Naturalism," the conclusion is reached that ". . . the ideal of reasoning on the nature of things involves that comprehensive dimension of intelligibility which neither the formal nor the material sciences can offer us . . . [the] metaphysic [of a naturalist] co-ordinates nature and human experience better than any other world-hypothesis because it takes its lead directly from the most reliable knowledge at our command."

The longest chapter in the book is that which considers "Does Biology Afford a Sufficient Basis for Ethics?" Here the modern biological concepts of homeostasis and others are thoroughly discussed, the essential differences between factual and normative problems are highlighted and the conclusion is reached that ". . . no descriptive science as such, biological or otherwise, can serve as a *sufficient* basis for ethics proper. . . . a principle derived exclusively from biological data, such as homeostasis, can provide only one-half of ethical wisdom, the *instrumental* half. The other half . . . must come from a principle that performs a *normative* function in the sphere of conduct. . . ."

The author calls for a naturalistic view of ethics ". . . which would amount to a reconciliation of Immanuel Kant and John Stuart Mill, [and] could be named 'The *double aspect* theory of ethics' . . . the guiding principle of the double-aspect theory is not maximum harmonization of human desires or maximum attainment of happiness, but maximum harmonization of a life of happiness *and* a life of duty, or, to adapt a Leibnizian term to the present context, maximum attainment of 'compossible' ends."

In the context of the present times, a philosophy which offers some possibility of "composing" the bits and pieces of our knowledge into a wisdom for living in the tragic terms of this age is urgently needed. This little volume is valuable as a start for personal as well as professionally-philosophical thinking.

—*Harvey W. Culp*

## The Whole of Mathematics

THIS must surely be a book unique among mathematical works: *The Tree of Mathematics,* organized by Glenn James as Managing Editor (published by the Digest Press, 14068 Van Nuys Blvd., Pacoima, Calif., 386 pages and index, $5.50). Mr. James is editor of *Mathematics Magazine,* and a teacher at the University of California. He has pictured major topics in the form of a tree, the roots (in the soil of arithmetic) being plane geometry, algebra, trigonometry, and, with irrational numbers and analytic geometry, constituting the base from which the calculus arises as the trunk. Professor James himself contributes the section on the calculas. Branches and the rest of the exfoliation are twenty-five of the great categories which can follow to best advantage once rate of change is understood.

His twenty distinguished fellow-contributors have fallen in with the scheme which, pursued by men who are masters in their several fields and thoroughly well acquainted with the whole, gives the volume its singular interest. The list of contributors includes Richard Arens, Edwin F. Beckenbach, John W. Green and Magnus R. Hestenes of the University of California at Los Angeles, E. T. Bell, Aristotle D. Michal (deceased), Olga Tausky and John Todd of the California Institute of Technology, Richard Bellman of the Rand Corporation, Herbert Busemann of the University of Southern California, H. S. M. Coxeter of the University of Toronto, J. H. Curtiss, Executive Director, American Mathematical Society, Louis E. Diamond, Maurice Frechet of the University of Paris, Dick Wick Hall of Harpur College, E. Justin Hills of Los Angeles City College, D. H. Hyers, co-editor of the *Mathematics Magazine,* Robert C. James of Harvey Mudd College, Estella Mazziotta of University High School, Los Angeles, and Charles K. Robbins of Purdue university.

The text concentrates upon the ideas, principles, structure and processes which give each topic its integrity. The object is not routine, drill, manipulation, but understanding. As far as possible the reasoning is supplied primarily in the verbal continuity, the appropriate mathematical symbol or equation being introduced (as far as possible) as the technical equivalent. In addition any new principle of prime importance is set up in italic type, when first it occurs (a common good practice in textbooks), and the book thus managed becomes the beginnings of an organic encyclopedia. For this reason an index is practicable. It runs over 1200 entries. Since only arithmetic is presupposed, it follows that we have here a book that can be read—slowly and with labor for some, and at certain points hardly for many—as might any book or text. This is a considerable achievement when we examine the scope.

We predict a permanent place for this unique volume, many editions, and steady evolution into an ever-more comprehensive reference work that is, all the same, not a disjointed encyclopedia.

There are some minor typographical errors, but the type face is handsome and readable, the printing and binding are of professional standard. Some chapters (why not all?) supply short valuable bibliographies. All in all, this is the one single volume, so far as we know, for the philosopher who is only a mediocre mathematician; a valuable text for certain types of study courses; an indispensable book for those who have limited mathematics but work in a close way with mathematicians.

As the crisis in education arises from the relation of mathematics and science to the so-called humanities (as if mathematics were inhuman), this book is most timely.

—*F. L. Kunz*

## A Biological Must

DOVER Publications has made available in stout paper cover, well-printed, the well-known *Elements of Mathematical Biology* by Alfred J. Lotka (447 pages, double index, 1956, $2.45). This work, originally issued in 1924 as *Elements of Physical Biology,* is a classical statistical treatment of evolutionary transformations, then a section on kinetics, statics and dynamics, which later moves from energy transformations and correlatory apparatus in organisms to sensation and adjustments and finally to consciousness. There is little on morphology or morphogenesis, and thus the relation of man to nature is not (as it could not be, in those early years of this century) traced out as it *must* be, in terms of formal orders; since formal orders are essential to knowing, the work remains incomplete. Why then keep it in print? Because it is a classical collection of data indispensable for acquaintance with this field; and because it is at the same time provocative, not of thought about disconnected details, but of the whole vast range of the statistical aspects in life of kinetics, statics and dynamics. Anyone who is anybody in that field is drawn upon.

Some indications of the wider glance it affords may be chosen from the concluding chapter: "While the human species, as a mechanical going concern, has become organized into a social whole, the motivation that keeps it going has not undergone the same thorough-going organization, but continues to be in great measure individualistic in type. . . . The system works tolerably well, beyond reasonable expectation perhaps; . . . The competitive element which it introduces is not without salutory action. But, making proper allowance for this, one is left to ponder whether there may not, in due course, be evolved a superior system, that shall secure the interests of the community more directly, and with less loss by *internal friction* in the social machinery. . . . We are not left wholly without encouragement that the future evolution of our race may proceed in a direction that shall ultimately ease the conflict between man and man, and between man and the world at large."

This is the work of a cultivated man, who was practically also a statistician. We are therefore in the publisher's debt.

—*F. L. Kunz*